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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

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VERTICAL DESCENT AND LANDING TESTS OF A 0.13-SCALE MODEL OF THE CONVAIR XFY-1 VERTICALLY RISING AIRPLANE IN STILL AIR

TED NO. NACA DE 368

By Charles C. Smith, Jr., and Powell M. Lovell, Jr.

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Langley Field, Va.

CLASSIFIED DOCUMENT

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VERTICAL DESCENT AND LANDING TESTS OF A 0.13-SCALE MODEL OF THE CONVAIR XFY-1 VERTICALLY RISING AIRPLANE IN STILL AIR

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SUMMARY

An investigation is being conducted to determine the dynamic stability and control characteristics of a 0.13-scale flying model of the Convair XFY-1 vertically rising airplane. This paper presents the results of flight and force tests to determine the stability and control characteristics of the model in vertical descent and landings in still air.

The tests indicated that landings, including vertical descent from altitudes representing up to 400 feet for the full-scale airplane and at rates of descent up to 15 or 20 feet per second (full scale), can be performed satisfactorily. Sustained vertical descent in still air probably will be more difficult to perform because of large random trim changes that become greater as the descent velocity is increased. A slight steady head wind or cross wind might be sufficient to eliminate the random trim changes.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, an investigation is being conducted to determine the dynamic stability and control characteristics of a 0.13-scale flying model of the Convair XFY-1 vertically rising airplane. The first phase of this investigation, which was reported in reference 1, dealt with hovering flight at altitude and near the ground, preliminary landing and take-off tests in still air, and low-speed forward flight in gusty wind. Reference 2 presents the results of the second phase which covered the transition range of flight between hovering and normal unstalled forward flight. The present paper gives the results of an extension of this work to include vertical descent in still air and landings and take-offs in still air with a shock-absorbing landing gear.

The present phase of the investigation consisted primarily of flight tests of the model. The results were obtained mainly from pilots' observations and from studies of motion-picture records of the flights. A few force tests were made to supplement the flight-test results.

NOMENCLATURE AND SYMBOLS

In order to avoid confusion in terminology, which might arise because of the unusual operating attitudes of the model, it should be explained that the controls and motions of the model are referred to in conventional terms relative to the body system of axes; that is, the rudders on the vertical tails produce yaw about the normal (Z) axis, differential deflection of the elevons on the wings produces roll about the longitudinal (X) axis, simultaneous up or down deflection of the elevons produces pitch about the spanwise (Y) axis. Figure 1 shows the axes and the positive directions of the forces, moments, and linear and angular displacements.

The definitions of the symbols used in the present paper are as follows:

X fuselage axis

Y spanwise axis

Z normal axis

I_X moment of inertia about fuselage axis, slug-ft^2

I_Y moment of inertia about spanwise axis, slug-ft^2

I_Z moment of inertia about normal axis, slug-ft^2

θ angle of pitch, deg

ϕ angle of bank, deg

ψ angle of yaw, deg

β angle of sideslip, deg

α angle of attack, deg

V_D vertical descent velocity, ft/sec

g 32.2 ft/sec/sec

MODEL

A photograph of the model is shown as figure 2 and a sketch showing some of the more important dimensions is shown in figure 3. The model had a modified triangular wing and modified triangular vertical tail surfaces mounted symmetrically above and below the fuselage and an eight-blade, dual-rotating, fixed-pitch propeller (two four-blade elements in tandem) powered by a 5-horsepower electric motor. Geometric characteristics of the model are presented in table I. For take-off and landing tests, shock-absorbing landing gear which made use of metered oil damping and an air spring were installed on the model instead of the essentially rigid wire landing gear used previously. The important geometric characteristics of the shock-absorbing landing gear are presented in table I. The model does not represent the final configuration of the airplane because it was constructed before the final design revisions were made. Moreover, the model was not exactly a 0.13-scale model of the original design in all respects because it was designed from rather small drawings and some slight inaccuracies occurred in obtaining the dimensions. The differences between the model and the final airplane configuration, however, are not believed to be great enough to alter appreciably the results presented in this paper.

The center of gravity was at the design location, 0.15 mean aerodynamic chord and 5.0 inches (full scale) above the thrust line. The weight and moments of inertia of the model, without the shock-absorbing landing gear, scaled up to full scale were within 10 percent of the calculated values for the airplane as shown in the following table:

	Model, scaled up (with shock struts)	Model, scaled up (without shock struts)	Full-scale airplane
Weight, lb	18,320	16,000	16,250
I_X, slug-ft^2	19,152	10,900	12,016
I_Y, slug-ft^2	37,410	25,100	23,361
I_Z, slug-ft^2	42,200	29,000	30,647

Maneuvering was accomplished by means of flap-type elevons and rudders operating in the propeller slipstream using the following control travels:

Total differential deflections of elevons, deg	54 right, 54 left
Simultaneous deflections of elevons, deg	25 up, 25 down
Rudder deflection, deg	25 right, 25 left

These controls were remotely operated by the pilots and were deflected by flicker-type (full-on, full-off) pneumatic servomechanisms which were controlled by electric solenoids. Three separate pilots were used to control the model in pitch, roll, and yaw in order that they might give careful attention to studying the motions of the model about each of the axes. For convenience, in most of the flights the rolling motions of the model were slowed by a rate-gyro damping device so that the model could be flown more smoothly in roll. A manual override was used with the damping device so that the model could be controlled and reoriented with respect to the pilots' position. The control actuating mechanisms used with the roll dampers were proportional-type mechanisms which deflected an amount proportional to the rate of roll. The manual override was a flicker-type control and produced full control deflection at the command of the pilot.

APPARATUS AND TESTS

The investigation covered in the present paper consisted of flight tests and force tests of the model. Stability, controllability, and general flight behavior were determined either quantitatively from motion-picture records of the flights and force-test data or qualitatively from the pilots' observations. General flight behavior is a term used to describe the overall flight characteristics of a model and indicates the ease with which the model can be flown. In effect, the general flight behavior is much the same as the pilot's opinion of the flying qualities of an airplane and indicates whether stability and controllability are adequate and properly proportioned.

The flight tests were made with test equipment and technique similar to that illustrated in figure 4 and described in references 1 and 2 or with some adaptation of this equipment and technique. The descriptions given in these references are more complete than that given in the present paper and may therefore be of interest to the reader.

Vertical-Descent Tests

Flight tests were made in the Langley 20-foot free-spinning tunnel to determine the stability and control characteristics of the model at various rates of descent. These flight tests were made by hovering the model in the test section of the vertical tunnel and then starting the upward flow of air and increasing the airspeed to the desired velocity. The thrust was adjusted as the airspeed was changed so that the model remained in the same approximate location in the test section. The range of airspeed covered in the tests extended from zero for hovering flight up to a descent speed representing 33 feet per second, full scale.

Flight tests were also made in the return passage of the Langley full-scale tunnel in still air to determine the flight behavior of the model during high rates of descent from a height which represented 400 feet for the full-scale airplane. In these tests the model was flown in steady hovering flight at a height representing approximately 400 feet and then descended vertically to landing at velocities of about 15 or 20 feet per second (full-scale speed).

In order to supplement the flight-test results, force tests were made with a separate force-test model mounted on the carriage of the Langley tank no. 1. This facility was used because it provided a range of very low test airspeeds which could be closely controlled. The force-test model was sting-mounted ahead of the carriage and a strain-gage balance and recording instruments provided continuous records of forces and moments. Tests were made with the model at 0° angle of pitch for a range of descent velocities extending from 0 to 42 feet per second (full-scale speed). Additional tests were also made to determine the rolling moment produced by full differential elevon deflection with the model in the static thrust condition (zero descent velocity). All the force tests were made at approximately half-thrust as a precaution against overloading the balance and overheating the model motor.

Take-Offs and Landings in Still Air

Flight tests were made in the return passage of the Langley full-scale tunnel in still air to determine the landing and take-off characteristics of the model with shock-absorbing landing gear installed. Vertical take-offs were accomplished by rapidly increasing the speed of the propellers until the model took off. As in reference 1 the take-offs were not as rapid as desired, because the model did not have enough excess power. Unrestrained landings were made by decreasing the speed of the propellers so that the model descended slowly until the landing gear was about 7 feet (full-scale distance) above the ground. At this point the power was cut off completely and the model dropped to the ground.

RESULTS AND DISCUSSION

Vertical Descent

Sustained vertical descent.- In hovering flight in the test section of the Langley 20-foot free-spinning tunnel the model could be flown smoothly and easily by the pilots. With the tunnel running to simulate sustained vertical descent, however, the model was more difficult to fly. In fact, the model could not be controlled indefinitely at any of the speeds covered in the vertical-descent tests. It could be flown steadily at the beginning of each flight for a short period of time but became increasingly more difficult to fly as time elapsed because of the development of large random fluctuations in trim. A study of the motion-picture records of the flight tests in the spin tunnel indicated that the model could consistently make successful descents for times representing 400- to 500-foot distances for the full-scale airplane. In some cases, descents were made for distances representing as much as 3,000 feet before the pilot lost control. In all cases, however, the model eventually went out of control. Although this difficulty with the random trim fluctuations was evident in yaw and pitch, the flights usually ended with the roll pilot losing control of the model. The model was more difficult to fly at the higher rates of descent than at the lower rates, apparently because of an increase in the magnitude and frequency of the fluctuations.

Since the model was flown by three pilots located so that each could observe the motions of the model about a given axis, a divergence in roll caused the yaw and pitch pilots to lose orientation and consequently lose control of the model so that it crashed. The pilot of the airplane, however, could not lose orientation in this manner with respect to the airplane and would consequently not lose control of it in yaw and pitch. Such a condition would probably be considered unsatisfactory, however, if the pilot could not stop the rolling motion.

Samples of time histories taken from force tests (fig. 5) show the variation of rolling moment with time for descent velocities of 0, 8, 17, 25, 33, and 42 feet per second full-scale speed. Fluctuations similar to these were also noticed in force-test records of pitch, yaw, side force, and normal force but not in longitudinal force. The force-test data may not represent the characteristics of the flight-test model exactly, because they were made on a separate force-test model. However, the data are believed to give a qualitative illustration of the rolling-moment fluctuations encountered in the flight tests. Some idea of the importance of these fluctuations can be gained by comparing them with measurements of the elevon effectiveness of the flight-test model which showed a maximum rolling moment representing 7,200 foot-pounds for the airplane. It is evident, therefore, that the rolling-moment fluctuations are of the same order of magnitude as the aileron rolling moments. The aileron rolling moment would actually be expected to be less in vertical descent than in hovering because of the reduction in dynamic pressure of the slipstream over the aileron which results from the descent velocity. For example, a descent velocity of 42 feet per second would be expected to reduce the aileron rolling moment by about 22 percent.

In both the flight and force tests, the force and moment fluctuations did not start as soon as the descent was started but there was an interval of time after the desired test speed had been reached before the fluctuations started. This time interval became smaller with an increase in the test speed. These facts indicated that one possible source of the fluctuation might have been large vortices or eddies which were probably produced by the propeller slipstream as it slowed down at a considerable distance behind the model. As the model backed into these eddies, the sidewise components of flow apparently caused changes in the various forces and moments. Unpublished data obtained from force tests of an isolated propeller in cross winds show that small side winds can cause large changes in all the forces and moments except longitudinal force. The random nature of the eddies would account for the random character of the force and moment fluctuations. Inasmuch as the eddies were created far behind the model, the fluctuations did not start as soon as the model started backing down.

During sustained vertical descent in a slight head wind or cross wind, the large random trim changes will probably not be experienced. The data of reference 3 showed that the random trim changes caused by recirculation of the slipstream during hovering in a confined area could be eliminated by a steady wind perpendicular to the thrust axis.

Vertical descent from 400 feet.- Additional data to supplement the spin-tunnel tests were obtained from vertical-descent tests made in the return passage of the Langley full-scale tunnel from a height representing about 400 feet for the full-scale airplane. This height seemed significant because of a Navy requirement that the airplane should be capable of performing transition flight at altitudes of less than 400 feet. Rapid descents were made, therefore, from this height all the way to the ground. The rates of descent covered in the tests represented values of about 15 or 20 feet per second for the full-scale airplane.

All these vertical-descent flights were easy to perform; in fact, the model seemed about as easy to fly as in hovering flight. Apparently the height at which these vertical descents were started was not great enough to permit the development of the large eddies suggested in the preceding section. The slipstream can be felt to be very strong at a distance representing 400 feet for the full-scale airplane behind the model and apparently spreads out smoothly when it strikes the ground.

Landings and Take-Offs in Still Air

In general, unrestrained take-offs and landings were easy to perform as was the case in the preliminary tests described in reference 1 for which the model had a relatively rigid wire landing gear. After touchdown the behavior of the model was much better with the shock-absorbing landing gear than with the wire landing gear because the model did not bounce as much. Landings with the shock-absorbing gear were considerably easier to perform because the reduced bouncing permitted higher rates of descent and larger angles of yaw and pitch at the time of touchdown.

In the landings following the rapid descents from a height representing 400 feet altitude for the full-scale airplane, very little flare could be made because of the limited power of the model (approximately 5 percent excess thrust). Inasmuch as the rates of descent at the time of touchdown were probably on the order of 15 to 20 feet per second (full scale) and the air pressure in the shock-absorbing landing gear had been increased to prevent bottoming, considerable bouncing occurred.

Take-offs with the shock-absorbing landing gear were not noticeably different from those with the wire landing gear described in reference 1. In particular, the sidewise motion of the model as it left the ground was not diminished by replacing the wire landing gear with the shock struts. It had been anticipated that take-offs with the shock-absorbing gear might be somewhat better than with the rigid gear (as pointed out in ref. 1) because the pilot could see the model beginning to tilt as a result of any out-of-trim moments as the power was being brought up, and could apply corrective control before the model left the ground. Apparently, however, the shock struts were so strong and stiff that the elevator and rudder were not capable of effecting any correction while the landing gear was in contact with the ground.

CONCLUSIONS

The following conclusions were drawn from the results of flight and force tests of a 0.13-scale flying model of the Convair XFY-1 vertically rising airplane during vertical descent and landings in still air:

1. Landings, including vertical descent from altitudes representing up to 400 feet for the full-scale airplane and at rates of descent up to 15 or 20 feet per second (full scale), can be performed satisfactorily.

2. Sustained vertical descent in still air probably will be more difficult to perform because of large random trim changes that become

greater as the velocity is increased. A slight steady head wind or cross wind might be sufficient to eliminate the random trim changes.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 4, 1954.

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Thomas A. Harris
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2. Lovell, Powell M., Jr., Kirby, Robert H., and Smith, Charles C., Jr.: Flight Investigation of the Stability and Control Characteristics of a 0.13-Scale Model of the Convair XFY-1 Vertically Rising Airplane During Constant-Altitude Transitions - TED No. NACA DE 368. NACA RM SL53E18, Bur. Aero., 1953.

3. Smith, Charles C., Jr., Lovell, Powell M., Jr., and Bates, William R.: Effect of the Proximity of the Ground on the Stability and Control Characteristics of a Vertically Rising Airplane Model in the Hovering Condition. NACA RM L51G05, 1951.

TABLE I.- GEOMETRIC CHARACTERISTICS OF THE MODEL

Weight, lb	35.00
Wing (modified triangular plan form):	
Sweepback, deg	55
Airfoil section	NACA 63-009 modified
Aspect ratio	1.90
Taper ratio (root to theoretical tip)	5.23
Area (total to center line), sq in.	818.95
Span (theoretical), in.	39.49
Mean aerodynamic chord, in.	23.94
Span of elevon (each), in.	15.37
Chord of elevon, in.	2.92
Dihedral angle, deg	0
Overall length of model, in.	49.40
Fuselage length, in.	45.40
Vertical tails (modified triangular plan form):	
Sweepback, deg	40
Airfoil section	NACA 63-009 modified
Aspect ratio	3.18
Taper ratio (root to theoretical tip)	3.15
Area (total to center line), sq in.	379.88
Span, in.	34.73
Mean aerodynamic chord, in.	13.07
Span of top rudder, in.	14.13
Span of bottom rudder, in.	11.13
Chord of rudders, in.	2.85
Propellers (eight-blade dual-rotating):	
Diameter, in.	23.85
Hamilton Standard design, drawing number	3155-6-1.5
Solidity, one blade	0.0475
Gap, in.	3.00
Shock-absorbing landing gear	
Stroke (maximum), in.	2.83
Stroke under one g, in.	approx. 2.13

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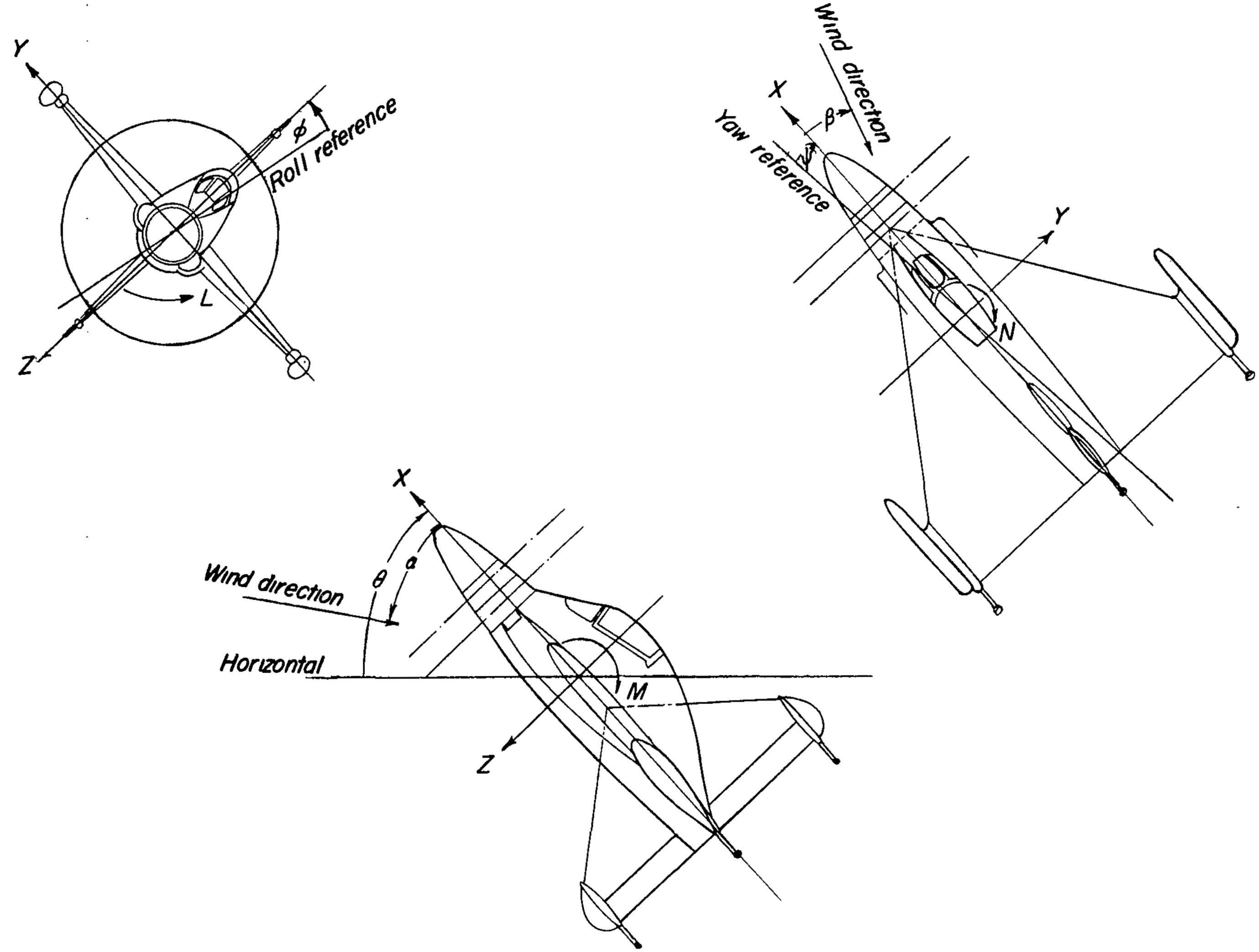

Figure 1.- The body system of axes. Arrows indicate positive directions of forces, moments, and linear and angular displacements.

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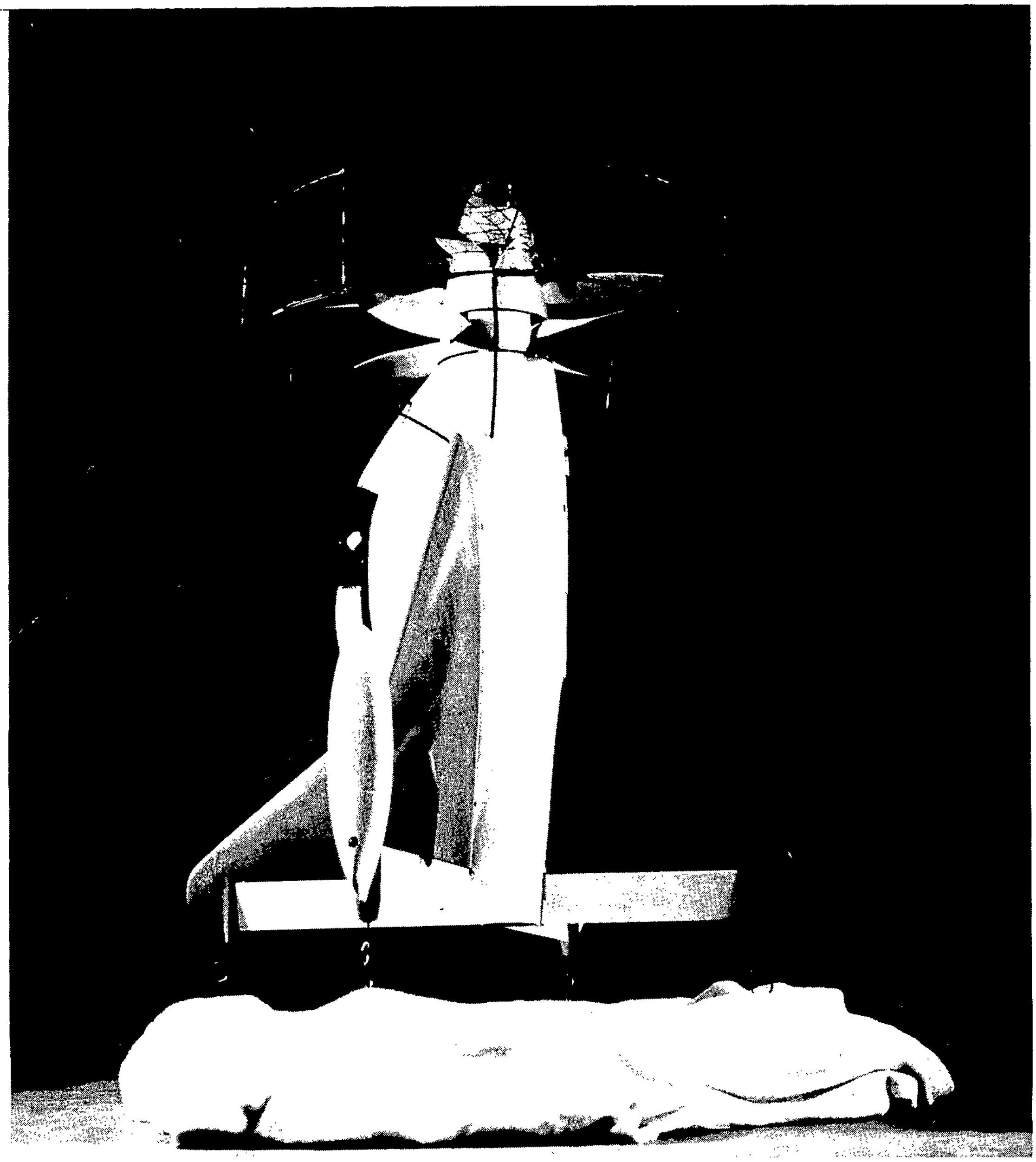

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Figure 2.- The Convair XFY-1 model with propeller guard.

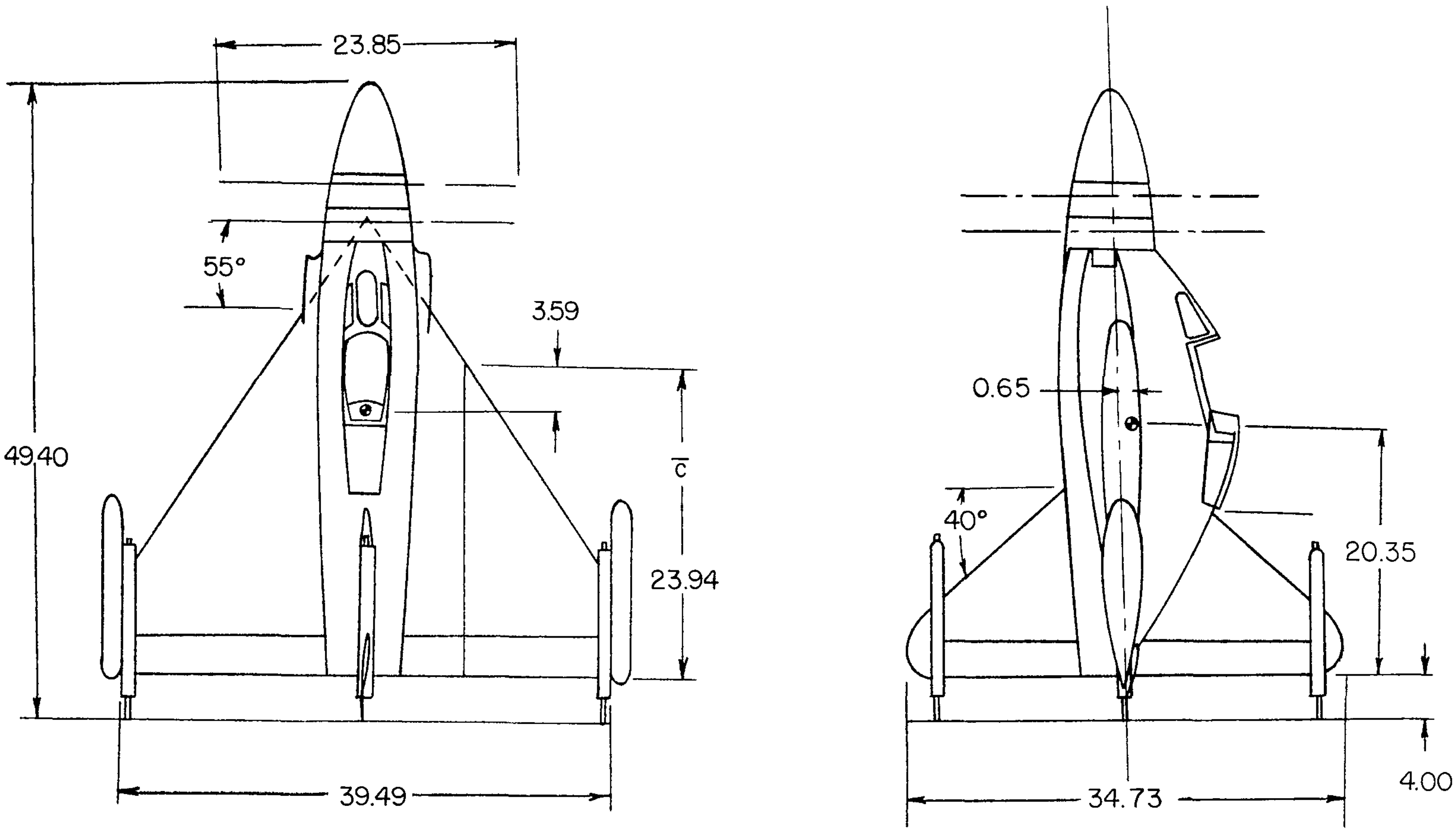

Figure 3.- The Convair XFY-1 vertically rising airplane model. All dimensions are in inches.

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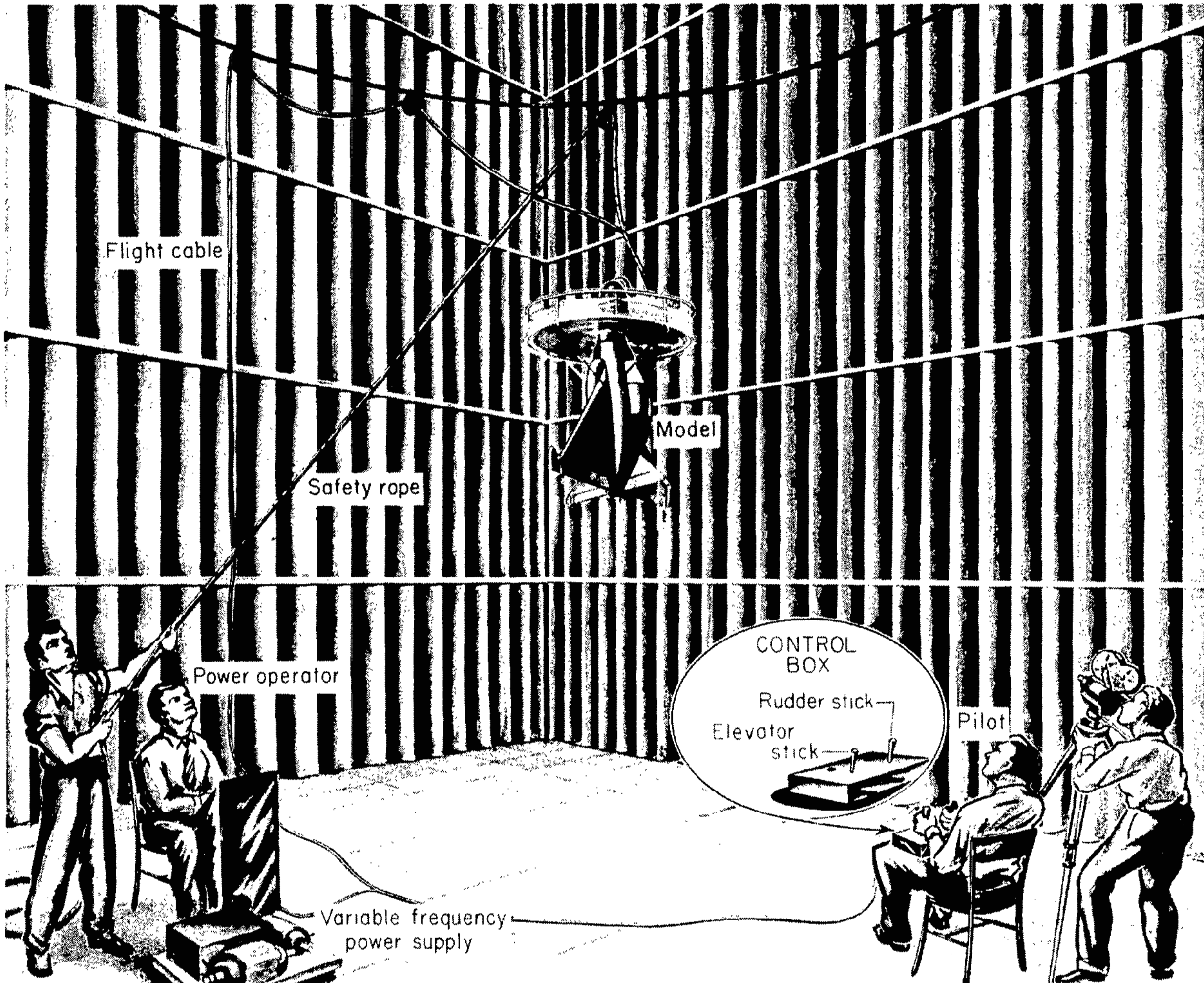

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Figure 4.- Sketch of test setup used in return passage of Langley full-scale tunnel.

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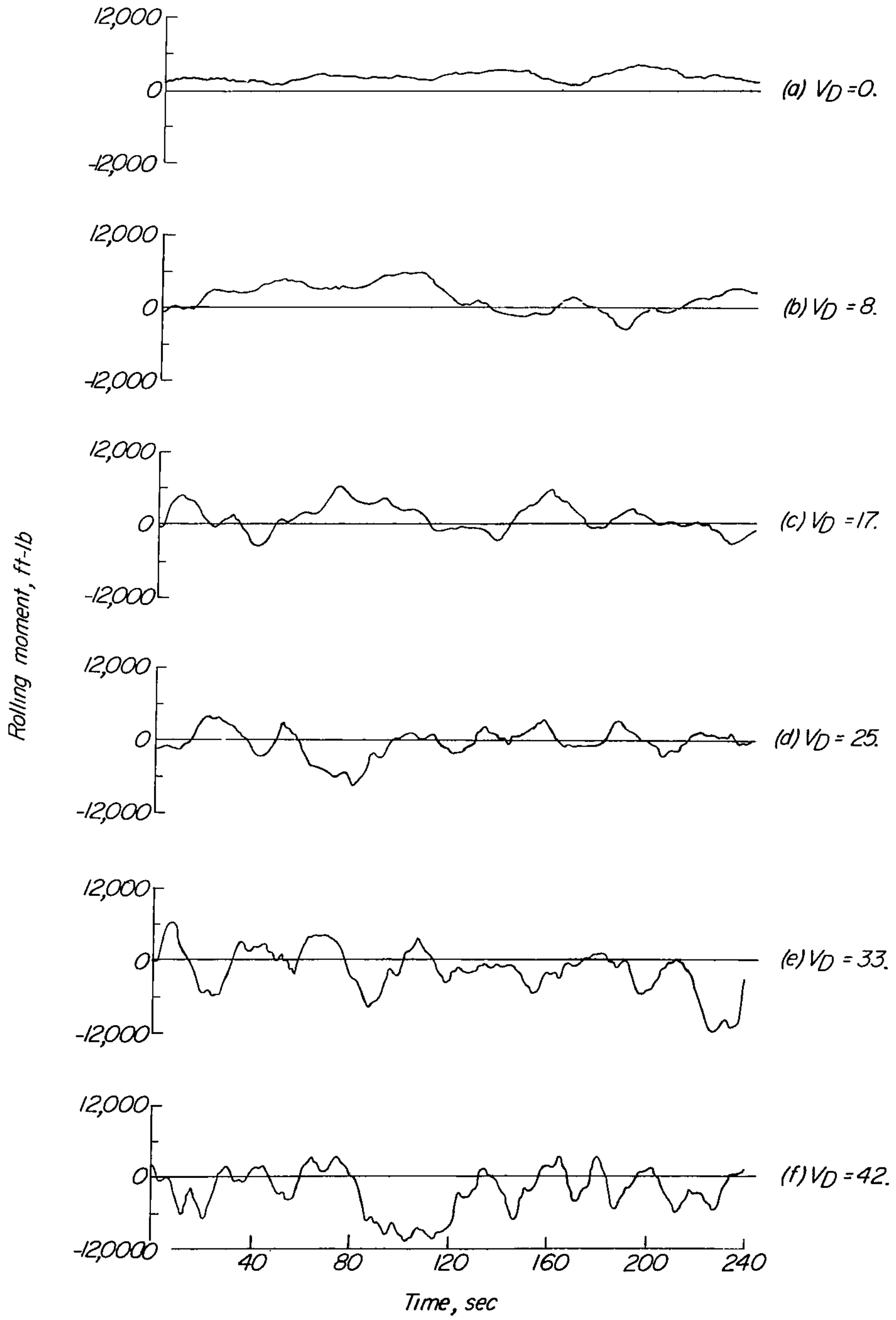

Figure 5.- Variation of rolling moment with time for various rates of descent.

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